Clay Content Optimization Test for Aggregate Surfacing (November 2018)

The following 21 pages in this document provide a summary report and five excel worksheets for performing the clay content optimization procedure for aggregate surfacing used on unpaved roads. This procedure determines the optimum clay content in aggregate surfacing that will resist rutting and also help maximize the retention of chloride dust abatement materials. The Report, Excel worksheets and instructions are intended to help experienced consultant laboratories complete the process in an efficient and accurate manner. Please contact the following individual if assistance is needed:

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[redacted]

August 30, 2017

Client [redacted]

Project [redacted]

HCE Project No.: 17-8088

Summary of Testing

A sample of the [redacted] gravel/filler blend (HCE Lab No. 17-1156) was obtained by Steve Monlux on August 10, 2017. This sample was used to perform mix design testing with the addition of calcium chloride and varying percentages of bentonite.

Initial testing consisted of sieve analysis of the as-received sample to verify it compared well to the stockpile averages from samples taken during production (see Attachment 1, one page). Once this had been determined, moisture-density curves for each of the selected bentonite percentages were developed to determine maximum dry density and optimum moisture content. These results are summarized below.

Modified Moisture Density Relationship (ASTM D1557)			
Percent Bentonite	2	3	4
Percent Calcium Chloride	1.5	1.5	1.5
Maximum Dry Density (pcf)	141.2	141.2	140.7
Optimum Moisture (%)	5.6	5.7	5.9

A split of a production sample of the [redacted] gravel with 2% added bentonite (HCE Lab No. 17-1155) had also obtained by Steve Monlux. This sample was tested for comparison with sieve analysis results from [redacted] The sample was also tested for plasticity index (see Attachment 2, one page). As results indicated a fairly high plasticity at the assumed percent 2% added bentonite, it was decided to perform CBR testing at slightly lower percentages of added bentonite than originally planned. Maximum dry densities and optimum moisture contents for these new blend percentages were estimated for purposes of evaluating the CBR results. Results of CBR and Chloride retention testing are summarized below (datasheets for Moisture-Density Curves, CBR and Chloride Retention are included in Attachment 3, 18 pages).

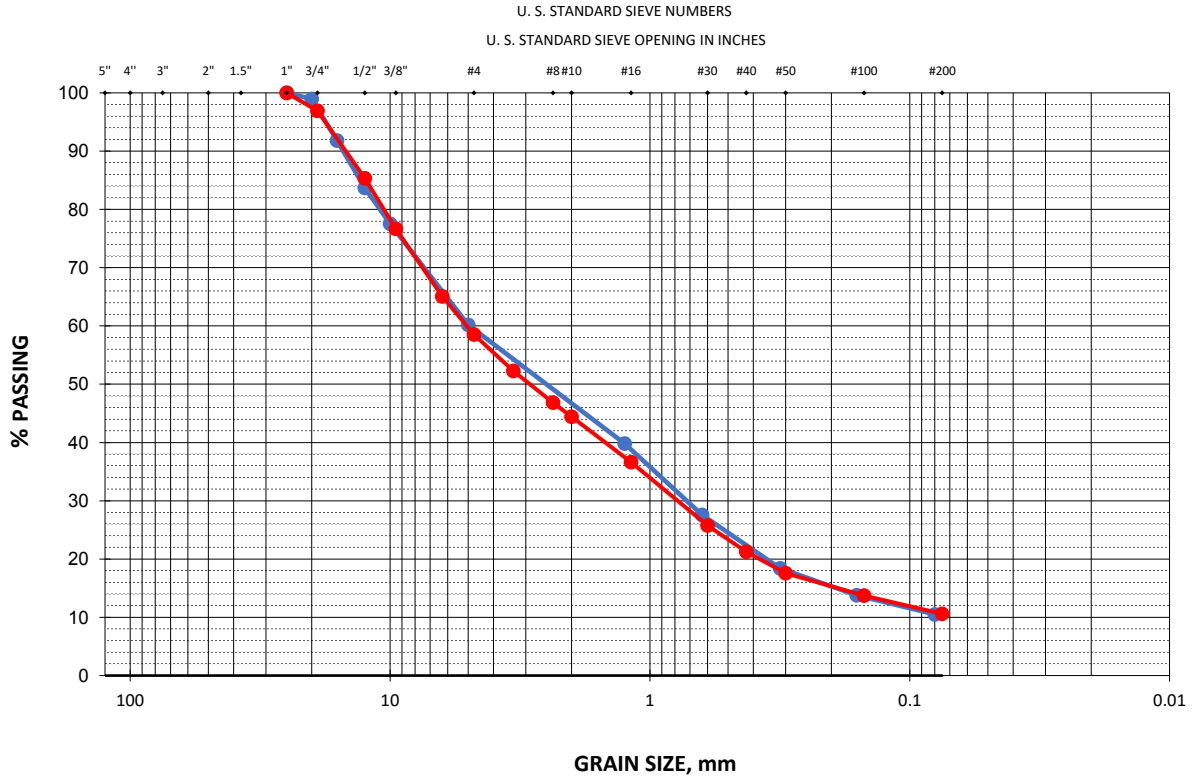
California Bearing Ratio (ASTM D1883) and Calcium Chloride Retention at 95 % Compaction			
Percent Bentonite	1.5	2.5	3.5
Percent Calcium Chloride	1.5	1.5	1.5
CBR @ 0.1 in.	51	50	51
CBR @ 0.2 in.	56	60	60
Calcium Chloride Retention (%)	36	41	41

[redacted]

[redacted]

August 16, 2017

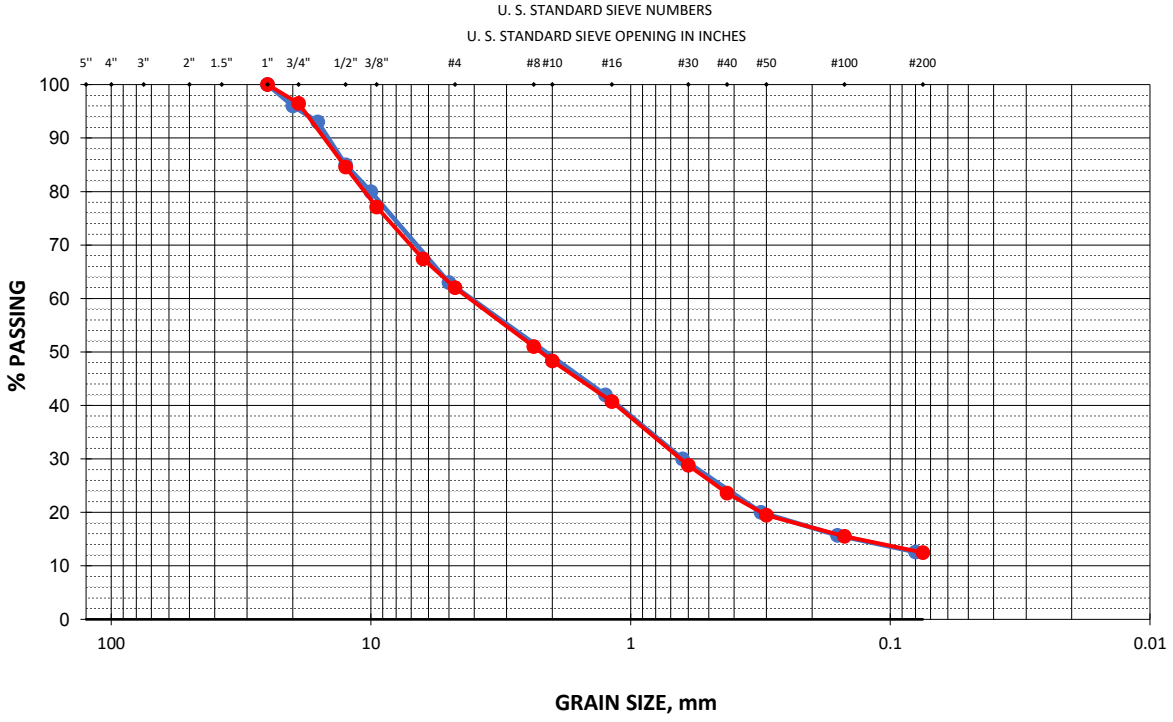
[redacted] Average			Holman Sample Lab No. 17-1156			
	% Passing			% Passing		
Sieve Size	w/2 % Bent	Agg only	Sieve Size	Buckets 1-8	Buckets 9-16	Average
25.000	100	100	25.000	100	100	100
20.000	99	99	19.000	96.6	97.2	97
16.000	92	92	12.500	85.1	85.6	85
12.500	84	84	9.500	76.7	76.6	77
10.000	78	78	6.300	65.5	64.6	65
5.000	61	60	4.750	58.9	58.2	59
1.250	41	40	3.350	52.6	52.0	52
0.630	29	28	2.360	47.3	46.4	47
0.315	20	18	2.000	44.7	44.1	44
0.160	15.5	14	1.180	36.8	36.5	37
0.080	12.3	10.5	0.600	25.8	25.7	26
			0.425	21.3	21.2	21
			0.300	17.6	17.5	18
			0.150	13.8	13.7	14
			0.075	10.6	10.6	10.6



[redacted]

[redacted] August 16, 2017

[redacted] Sample #12		Holman Split - Lab No. 17-1155	
Sieve Size	% Passing	Sieve Size	% Passing
25.000	100	25.000	100
20.000	96	19.000	97
16.000	93	12.500	85
12.500	85	9.500	77
10.000	80	6.300	67
5.000	63	4.750	62
1.250	42	2.360	51
0.630	30	2.000	48
0.315	20	1.180	41
0.160	16	0.600	29
0.080	12.6	0.425	24
		0.300	20
		0.150	16
		0.075	12.5
Liquid Limit	not provided	Liquid Limit	33
Plastic Limit	not provided	Plastic Limit	15
Plasticity Index	not provided	Plasticity Index	18



T-180 Batching and Graph

Bentonite	Percentage to be added to Soil Mixture:	2.00%
	Moisture Content, %:	10.80%
Calcium Chloride	Percentage to be added to Soil Mixture:	1.50%
	Brine Concentration, %:	39.00%
Soil	Initial Moisture Content before mixing, %:	1.00%

Specimen ID	**A**		**B**		**C**		**D**		**E**	
Batching										
Soil	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**
Wet weight sample, g:	7265.0		7291.9		7581.2		7111.2		7005.7	
Dry Weight sample, g:		7193.1		7219.7		7506.1		7040.8		6936.3
Weight H2O in sample, g:		71.9		72.2		75.1		70.4		69.4
Bentonite										
Dry weight needed, g:		143.9		144.4		150.1		140.8		138.7
Wet weight needed, g:	159.4		160.0		166.3		156.0		153.7	
Weight H2O in additive, g:		15.5		15.6		16.2		15.2		15.0
Calcium Chloride										
Dry Wgt pure $CaCl_2$ needed, g:		110.1		110.5		114.8		107.7		106.1
Weight $CaCl_2$ Brine needed, g:	282.2		283.2		294.5		276.2		272.1	
Weight H_2O in Brine, g:		172.1		172.8		179.6		168.5		166.0
Mixture										
Target Moisture Content:		3.5%		4.8%		6.0%		7.3%		8.5%
Weight dry ingredients (w/$CaCl_2$), g:		7447.0		7474.6		7771.1		7289.3		7181.2
Weight H_2O needed, g:		260.6		355.0		466.3		528.5		610.4
Weight H_2O in soil & additives, g:		259.6		260.6		270.9		254.1		250.3
Weight H_2O to add:	1.0		94.5		195.4		274.4		360.1	

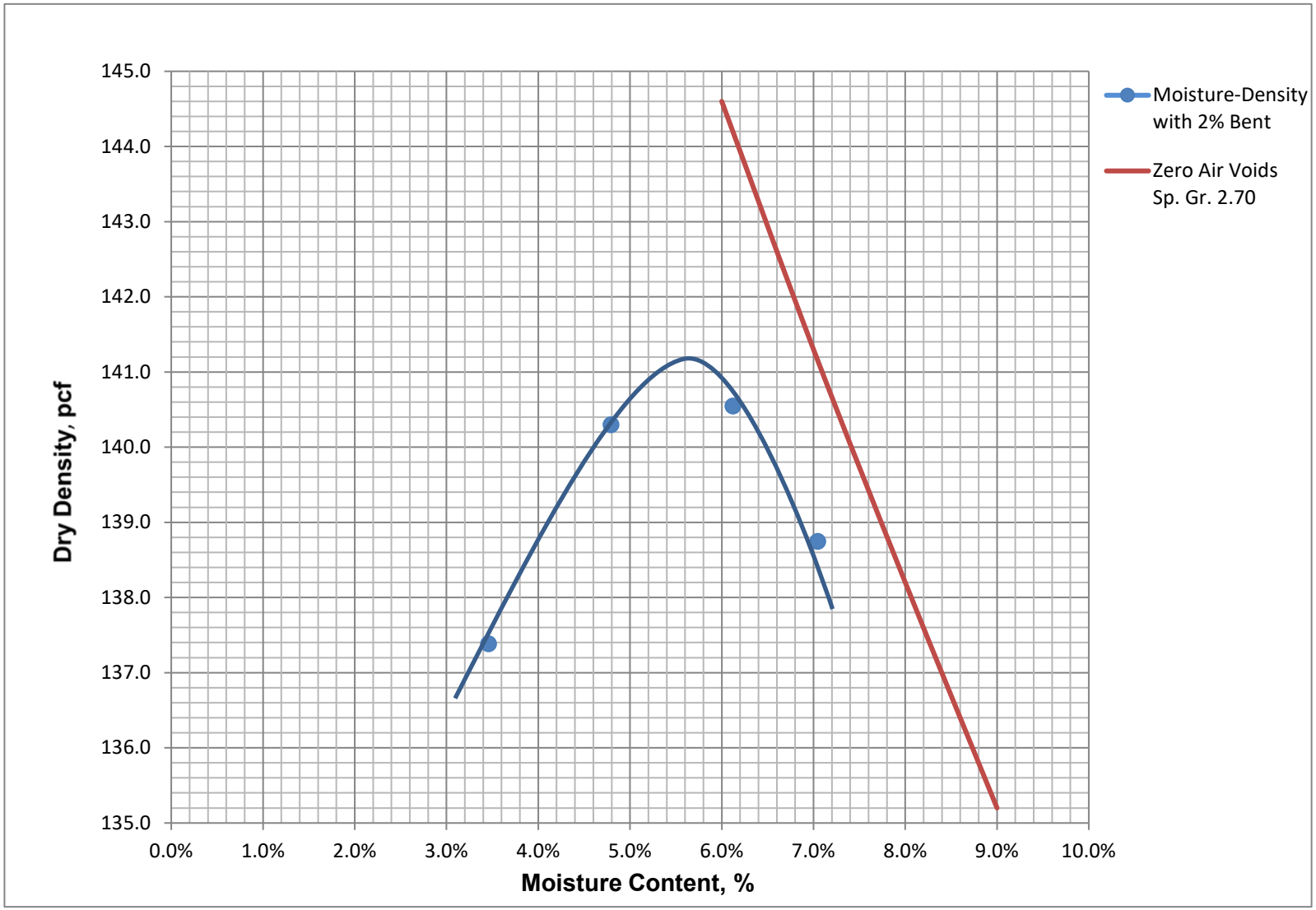
Compacted Specimen*	**A**	**B**	**C**	**D**	**E**
Weight mold + soil, g:	7598.0	7764.4	7836.8	7815.5	
Weight mold, g:	2757.0	2757.0	2757.0	2757.0	2757.0
Wet weight specimen, g:	4841.0	5007.4	5079.8	5058.5	
Wet density, pcf:	142.1	147.0	149.1	148.5	
Prelim dry density, pcf:	137.3	140.4	140.7	138.5	
Wet weight moisture sample, g:	4838.9	5004.1	5069.9	5050.8	
Dry weight moisture sample, g:	4677.1	4775.2	4777.5	4718.3	
% Moisture:	3.5%	4.8%	6.1%	7.0%	
Dry density comp. specimen, pcf:	137.4	140.3	140.5	138.7	

*Compacted specimen densities are calculated assuming use of 6-inch diameter mold, adjustment to formulas will be necessary if molds of other sizes are used.

Graph of Moisture-Density Relationship

Maximum Dry Density:	141.2

Optimum Moisture:	5.6



T-180 Batching and Graph

Bentonite	Percentage to be added to Soil Mixture:	3.00%
	Moisture Content, %:	10.80%
Calcium Chloride	Percentage to be added to Soil Mixture:	1.50%
	Brine Concentration, %:	39.00%
Soil	Initial Moisture Content before mixing, %:	1.00%

Specimen ID	**F**		**G**		**H**		**Melted**		**Blank**	
Batching										
Soil	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**
Wet weight sample, g:	6648.2		6784.5		7192.7		6755.5		6737.6	
Dry Weight sample, g:		6582.4		6717.3		7121.5		6688.6		6670.9
Weight H2O in sample, g:		65.8		67.2		71.2		66.9		66.7
Bentonite										
Dry weight needed, g:		197.5		201.5		213.6		200.7		200.1
Wet weight needed, g:	218.8		223.3		236.7		222.3		221.7	
Weight H2O in additive, g:		21.3		21.8		23.1		21.7		21.6
Calcium Chloride										
Dry Wgt pure $CaCl_2$ needed, g:		101.7		103.8		110.0		103.3		103.1
Weight $CaCl_2$ Brine needed, g:	260.8		266.1		282.1		265.0		264.3	
Weight H_2O in Brine, g:		159.1		162.3		172.1		161.6		161.2
Mixture										
Target Moisture Content:		3.5%		4.8%		6.0%		7.3%		8.5%
Weight dry ingredients (w/$CaCl_2$), g:		6881.5		7022.6		7445.2		6992.6		6974.1
Weight H_2O needed, g:		240.9		333.6		446.7		507.0		592.8
Weight H_2O in soil & additives, g:		246.2		251.3		266.4		250.2		249.5
Weight H_2O to add:	-5.4		82.3		180.3		256.8		343.3	

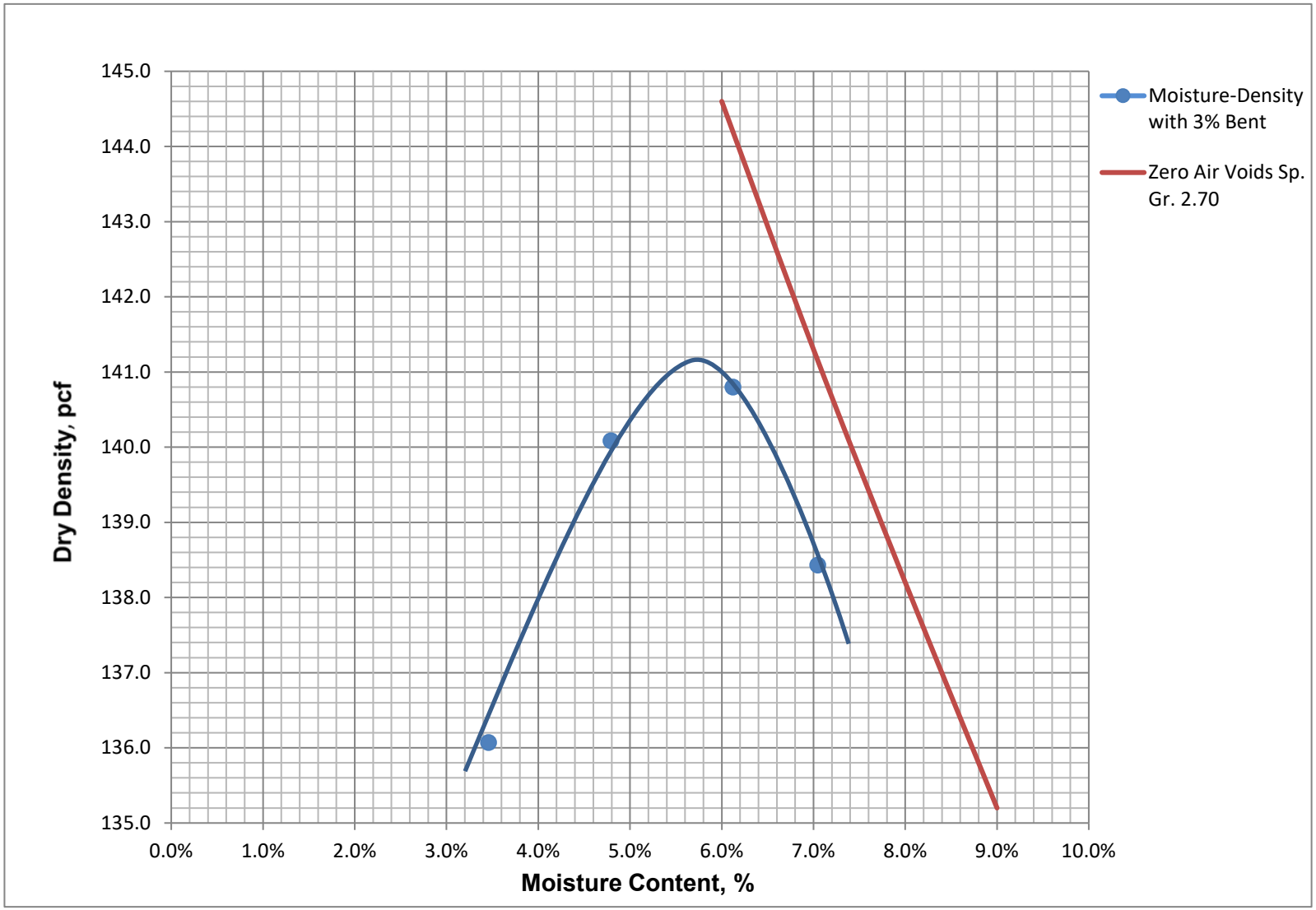
Compacted Specimen*	**F**	**G**	**H**	**Melted**	**Blank**
Weight mold + soil, g:	7547.7	7750.7	7841.4	7798.4	
Weight mold, g:	2757.0	2757.0	2757.0	2757.0	2757.0
Wet weight specimen, g:	4790.7	4993.7	5084.4	5041.4	
Wet density, pcf:	140.7	146.6	149.3	148.0	
Prelim dry density, pcf:	135.9	140.0	140.8	138.0	
Wet weight moisture sample, g:	4784.6	4989.0	5070.2	5034.0	
Dry weight moisture sample, g:	4628.5	4766.6	4782.0	4707.9	
% Moisture:	3.4%	4.7%	6.0%	6.9%	
Dry density comp. specimen, pcf:	136.1	140.1	140.8	138.4	

*Compacted specimen densities are calculated assuming use of 6-inch diameter mold, adjustment to formulas will be necessary if molds of other sizes are used.

Graph of Moisture-Density Relationship

Maximum Dry Density:	141.2

Optimum Moisture:	5.7



T-180 Batching and Graph

Bentonite	Percentage to be added to Soil Mixture:	4.00%
	Moisture Content, %:	10.80%
Calcium Chloride	Percentage to be added to Soil Mixture:	1.50%
	Brine Concentration, %:	39.00%
Soil	Initial Moisture Content before mixing, %:	1.00%

Specimen ID	**K**		**L**		**M**		**N**		**O**	
Batching										
Soil	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**
Wet weight sample, g:	6027.3		6176.5		6232.0		5691.1		5501.6	
Dry Weight sample, g:		5967.6		6115.3		6170.3		5634.8		5447.1
Weight H2O in sample, g:		59.7		61.2		61.7		56.3		54.5
Bentonite										
Dry weight needed, g:		238.7		244.6		246.8		225.4		217.9
Wet weight needed, g:	264.5		271.0		273.5		249.7		241.4	
Weight H2O in additive, g:		25.8		26.4		26.7		24.3		23.5
Calcium Chloride										
Dry Wgt pure $CaCl_2$ needed, g:		93.1		95.4		96.3		87.9		85.0
Weight $CaCl_2$ Brine needed, g:	238.7		244.6		246.8		225.4		217.9	
Weight H_2O in Brine, g:		145.6		149.2		150.6		137.5		132.9
Mixture										
Target Moisture Content:		4.0%		5.3%		6.5%		7.8%		9.0%
Weight dry ingredients (w/$CaCl_2$), g:		6299.4		6455.4		6513.4		5948.0		5750.0
Weight H_2O needed, g:		252.0		338.9		423.4		461.0		517.5
Weight H_2O in soil & additives, g:		231.1		236.8		238.9		218.2		210.9
Weight H_2O to add:	20.9		102.1		184.5		242.8		306.6	

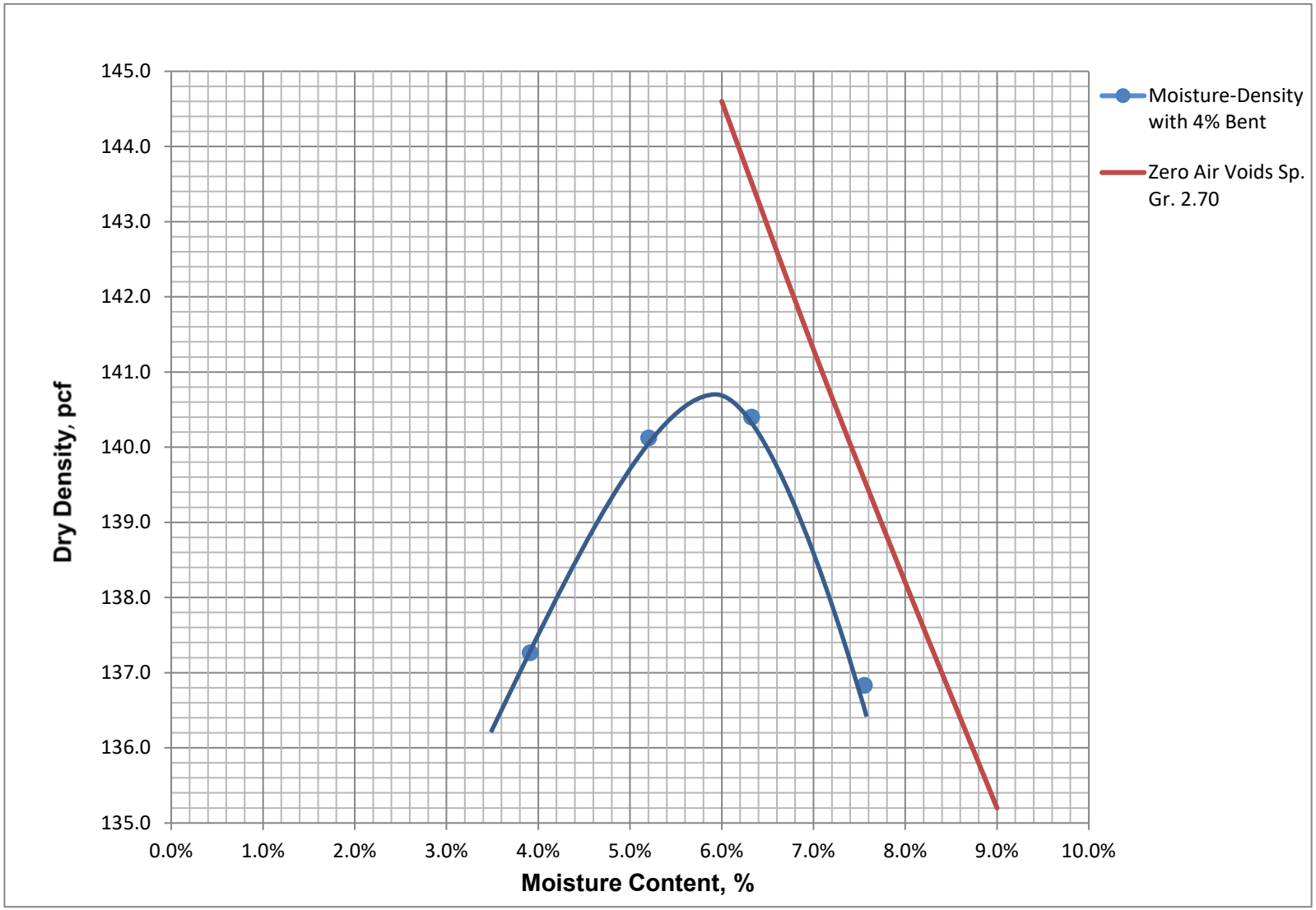
Compacted Specimen*	**K**	**L**	**M**	**N**	**O**
Weight mold + soil, g:	7615.0	7777.6	7841.2	7769.3	
Weight mold, g:	2757.0	2757.0	2757.0	2757.0	
Wet weight specimen, g:	4858.0	5020.6	5084.2	5012.3	
Wet density, pcf:	142.6	147.4	149.3	147.2	
Prelim dry density, pcf:	137.2	140.1	140.2	136.6	
Wet weight moisture sample, g:	4852.6	5009.4	5065.2	4998.9	
Dry weight moisture sample, g:	4669.9	4761.7	4763.9	4647.8	
% Moisture:	3.9%	5.2%	6.3%	7.6%	
Dry density comp. specimen, pcf:	137.3	140.1	140.4	136.8	

*Compacted specimen densities are calculated assuming use of 6-inch diameter mold, adjustment to formulas will be necessary if molds of other sizes are used.

Graph of Moisture-Density Relationship

Maximum Dry Density:	140.7

Optimum Moisture:	5.9



CBR Batching and Compaction

Bentonite	Percentage to be added to Soil Mixture:	1.50%
	Moisture Content, %:	10.80%
Calcium Chloride	Percentage to be added to Soil Mixture:	1.50%
	Brine Concentration, %:	39.00%
Soil	Initial Moisture Content before mixing, %:	0.90%
Mixture	Maximum Dry Density, from T180, pcf:	141.50
	Optimum Moisture, from T180, pcf:	5.50

Specimen ID	**A**		**B**		**C**	
Batching Soil	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**
Wet weight sample, g:	8903.0		8998.0		9412.0	
Dry Weight sample, g:		8823.6		8917.7		9328.0
Weight H2O in additive, g:		79.4		80.3		84.0
Bentonite						
Dry weight needed, g:		132.4		133.8		139.9
Wet weight needed, g:	146.6		148.2		155.0	
Weight H2O in additive, g:		14.3		14.4		15.1
Calcium Chloride						
Dry Wgt pure $CaCl_2$ needed, g:		134.3		135.8		142.0
Weight $CaCl_2$ Brine needed, g:	344.5		348.1		364.2	
Weight H_2O in Brine, g:		210.1		212.4		222.1
Mixture						
Target Moisture Content:		5.5%		5.5%		5.5%
Weight dry ingredients, g:		9090.3		9187.3		9610.0
Weight H_2O needed, g:		500.0		505.3		528.5
Weight H_2O in soil & additives, g:		303.8		307.1		321.2
Weight H_2O to add:	196.1		198.2		207.4	
Compacting						
Mold ID	**1**		**11**		**12**	
Number of blows	**8**		**16**		**32**	
Weight mold + soil, g:	13396.4		13551.7		13553.5	
Weight mold, g:	8684.5		8654.8		8520.3	
Wet weight specimen, g:	4711.9		4896.9		5033.2	
Wet density, pcf:	138.3		143.8		147.8	
Prelim dry density, pcf:	131.1		136.3		140.1	
Wet weight moisture sample, 2 ea, g:	2068.6	2286.5	1736.5	2432.8	2193.6	2273.7
Dry weight moisture sample, 2 ea, g:	1960.5	2168.8	1644.7	2308.0	2081.1	2149.2
% Moisture:	5.5%	5.4%	5.6%	5.4%	5.4%	5.8%
% Moisture (Average):	5.5%		5.5%		5.6%	
Dry density comp. specimen, g:	131.2		136.3		139.9	
Compaction, % Max DD:	92.7%		96.3%		98.9%	
Initial Swell Reading, in:	0.029		0.033		0.019	
Final Swell Reading, In:	0.029		0.033		0.016	
Swell, %:	0.0%		0.0%		-0.1%	

CBR Batching and Compaction

Bentonite	Percentage to be added to Soil Mixture:	2.50%
	Moisture Content, %:	10.80%
Calcium Chloride	Percentage to be added to Soil Mixture:	1.50%
	Brine Concentration, %:	39.00%
Soil	Initial Moisture Content before mixing, %:	0.90%
Mixture	Maximum Dry Density, from T180, pcf:	141.20
	Optimum Moisture, from T180, pcf:	5.70

Specimen ID	**D**		**E**		**F**	
Batching Soil	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**
Wet weight sample, g:	8449.0		8499.0		8585.0	
Dry Weight sample, g:		8373.6		8423.2		8508.4
Weight H2O in additive, g:		75.4		75.8		76.6
Bentonite						
Dry weight needed, g:		209.3		210.6		212.7
Wet weight needed, g:	231.9		233.3		235.7	
Weight H2O in additive, g:		22.6		22.7		23.0
Calcium Chloride						
Dry Wgt pure $CaCl_2$ needed, g:		128.7		129.5		130.8
Weight $CaCl_2$ Brine needed, g:	330.1		332.1		335.4	
Weight H_2O in Brine, g:		201.4		202.6		204.6
Mixture						
Target Moisture Content:		5.7%		5.7%		5.7%
Weight dry ingredients, g:		8711.7		8763.3		8852.0
Weight H_2O needed, g:		496.6		499.5		504.6
Weight H_2O in soil & additives, g:		299.3		301.1		304.2
Weight H_2O to add:	197.2		198.4		200.4	
Compacting						
Mold ID	**13**		**14**		**20**	
Number of blows	**8**		**16**		**32**	
Weight mold + soil, g:	13378.7		13351.0		13720.6	
Weight mold, g:	8726.9		8499.1		8688.7	
Wet weight specimen, g:	4651.8		4851.9		5031.9	
Wet density, pcf:	136.6		142.5		147.7	
Prelim dry density, pcf:	129.2		134.8		139.8	
Wet weight moisture sample, 2 ea, g:	2074.4	1763.8	1692.4	2279.0	2073.7	1821.8
Dry weight moisture sample, 2 ea, g:	1964.7	1671.9	1598.4	2151.6	1958.0	1716.0
% Moisture:	5.6%	5.5%	5.9%	5.9%	5.9%	6.2%
% Moisture (Average):	5.5%		5.9%		6.0%	
Dry density comp. specimen, g:	129.4		134.5		139.3	
Compaction, % Max DD:	91.7%		95.3%		98.7%	
Initial Swell Reading, in:	0.023		0.013		0.024	
Final Swell Reading, In:	0.028		0.016		0.024	
Swell, %:	0.1%		0.1%		0.0%	

CBR Batching and Compaction

Bentonite	Percentage to be added to Soil Mixture:	3.50%
	Moisture Content, %:	10.80%
Calcium Chloride	Percentage to be added to Soil Mixture:	1.50%
	Brine Concentration, %:	39.00%
Soil	Initial Moisture Content before mixing, %:	0.90%
Mixture	Maximum Dry Density, from T180, pcf:	141.00
	Optimum Moisture, from T180, pcf:	5.90

Specimen ID	**G**		**H**		**I**	
Batching Soil	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**	**Batch weights**	**Calcs**
Wet weight sample, g:	7911.0		8013.0		8374.0	
Dry Weight sample, g:		7840.4		7941.5		8299.3
Weight H2O in additive, g:		70.6		71.5		74.7
Bentonite						
Dry weight needed, g:		274.4		278.0		290.5
Wet weight needed, g:	304.1		308.0		321.8	
Weight H2O in additive, g:		29.6		30.0		31.4
Calcium Chloride						
Dry Wgt pure $CaCl_2$ needed, g:		121.7		123.3		128.8
Weight $CaCl_2$ Brine needed, g:	312.1		316.1		330.4	
Weight H_2O in Brine, g:		190.4		192.8		201.5
Mixture						
Target Moisture Content:		5.9%		5.9%		5.9%
Weight dry ingredients, g:		8236.6		8342.8		8718.6
Weight H_2O needed, g:		486.0		492.2		514.4
Weight H_2O in soil & additives, g:		290.6		294.3		307.6
Weight H_2O to add:	195.4		197.9		206.8	
Compacting						
Mold ID	**22**		**112**		**221**	
Number of blows	**16**		**8**		**32**	
Weight mold + soil, g:	13436.0		13404.1		13647.2	
Weight mold, g:	8579.1		8735.2		8626.5	
Wet weight specimen, g:	4856.9		4668.9		5020.7	
Wet density, pcf:	142.6		137.1		147.4	
Prelim dry density, pcf:	134.7		129.4		139.2	
Wet weight moisture sample, 2 ea, g:	1770.0	1657.3	1463.1	2344.9	1804.6	1806.2
Dry weight moisture sample, 2 ea, g:	1673.1	1562.9	1377.0	2211.4	1700.7	1709.0
% Moisture:	5.8%	6.0%	6.3%	6.0%	6.1%	5.7%
% Moisture (Average):	5.9%		6.1%		5.9%	
Dry density comp. specimen, g:	134.6		129.1		139.2	
Compaction, % Max DD:	95.5%		91.6%		98.7%	
Initial Swell Reading, in:	0.000		0.020		0.027	
Final Swell Reading, In:	0.002		0.028		0.027	
Swell, %:	0.0%		0.2%		0.0%	

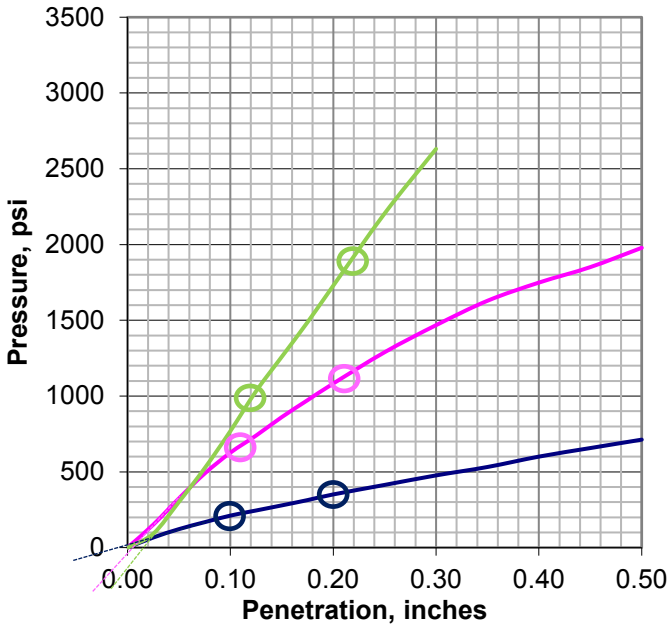
CBR Penetration Data

Penetration Piston*	Diameter	Area Face
	1.952	2.992924

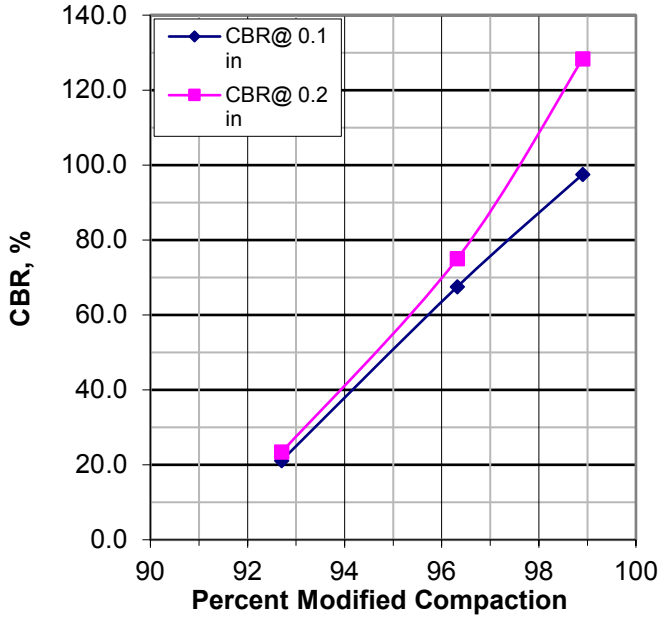
CBR Stress Strain Curve Plotting and Interpretation

Mold No.		**1**			**11**			**12**		
% Compaction		**92.7**			**96.3**			**98.9**		
Proving Ring Used*:		10,000 lb			10,000 lb			10,000 lb		
Minutes	Pen (in)	Dial	Load	Stress	Dial	Load	Stress	Dial	Load	Stress
0.0	0.000	0	0	0	0	0	0	0	0	0
0.5	0.025	199	199	66	453	453	151	274	274	92
1.0	0.050	365	365	122	973	973	325	904	904	302
1.5	0.075	502	502	168	1463	1463	489	1568	1568	524
2.0	0.100	632	632	211	1875	1875	626	2302	2302	769
2.5	0.125	733	733	245	2213	2213	739	3090	3090	1032
3.0	0.150	834	834	279	2578	2578	861	3770	3770	1260
3.5	0.175	938	938	313	2911	2911	973	4451	4451	1487
4.0	0.200	1050	1050	351	3240	3240	1083	5172	5172	1728
5.0	0.250	1238	1238	414	3859	3859	1289	6600	6600	2205
6.0	0.300	1426	1426	476	4393	4393	1468	7874	7874	2631
7.0	0.350	1592	1592	532	4875	4875	1629		0	0
8.0	0.400	1797	1797	600	5234	5234	1749		0	0
9.0	0.450	1966	1966	657	5540	5540	1851		0	0
10.0	0.500	2132	2132	712	5921	5921	1978		0	0
CBR at 0.1 in pen			21.1			67.5			97.5	
CBR at 0.2 in pen			23.4			75.0			128.3	

CBR Stress Strain Curve



CBR versus Percent Compaction



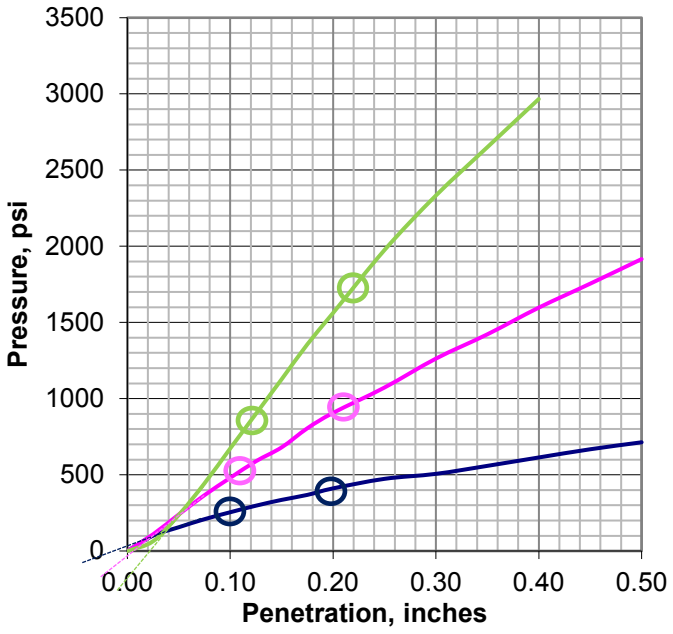
CBR Penetration Data

Penetration Piston*	Diameter	Area Face
	1.952	2.992924

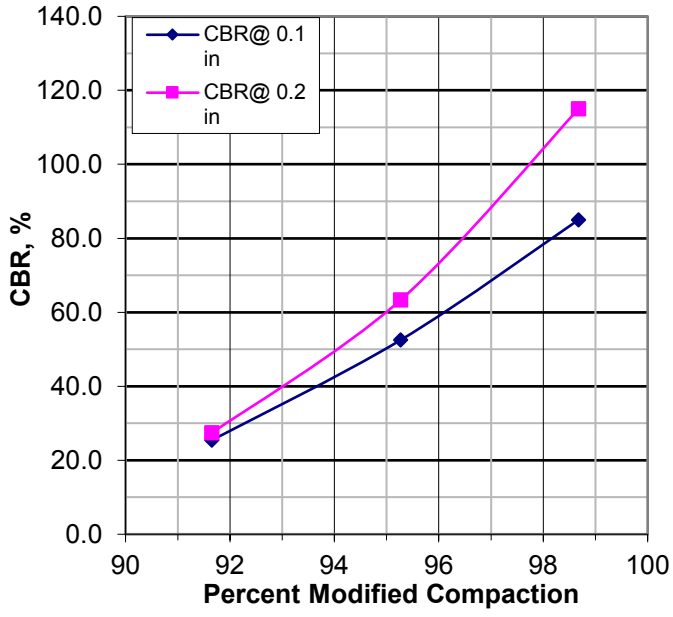
CBR Stress Strain Curve Plotting and Interpretation

Mold No.		**13**			**14**			**20**		
% Compaction		**91.7**			**95.3**			**98.7**		
Proving Ring Used*:		10,000 lb			10,000 lb			10,000 lb		
Minutes	Pen (in)	Dial	Load	Stress	Dial	Load	Stress	Dial	Load	Stress
0.0	0.000	0	0	0	0	0	0	0	0	0
0.5	0.025	301	301	101	328	328	110	192	192	64
1.0	0.050	467	467	156	718	718	240	710	710	237
1.5	0.075	625	625	209	1097	1097	367	1330	1330	444
2.0	0.100	761	761	254	1437	1437	480	2015	2015	673
2.5	0.125	890	890	297	1763	1763	589	2696	2696	901
3.0	0.150	1004	1004	335	2036	2036	680	3374	3374	1127
3.5	0.175	1102	1102	368	2411	2411	806	4061	4061	1357
4.0	0.200	1230	1230	411	2713	2713	906	4676	4676	1562
5.0	0.250	1417	1417	473	3211	3211	1073	5912	5912	1975
6.0	0.300	1515	1515	506	3779	3779	1263	6983	6983	2333
7.0	0.350	1672	1672	559	4256	4256	1422	7932	7932	2650
8.0	0.400	1837	1837	614	4780	4780	1597	8878	8878	2966
9.0	0.450	1998	1998	668	5251	5251	1754		0	0
10.0	0.500	2135	2135	713	5734	5734	1916		0	0
CBR at 0.1 in pen			25.4			52.5			85.0	
CBR at 0.2 in pen			27.4			63.3			115.0	

CBR Stress Strain Curve



CBR versus Percent Compaction



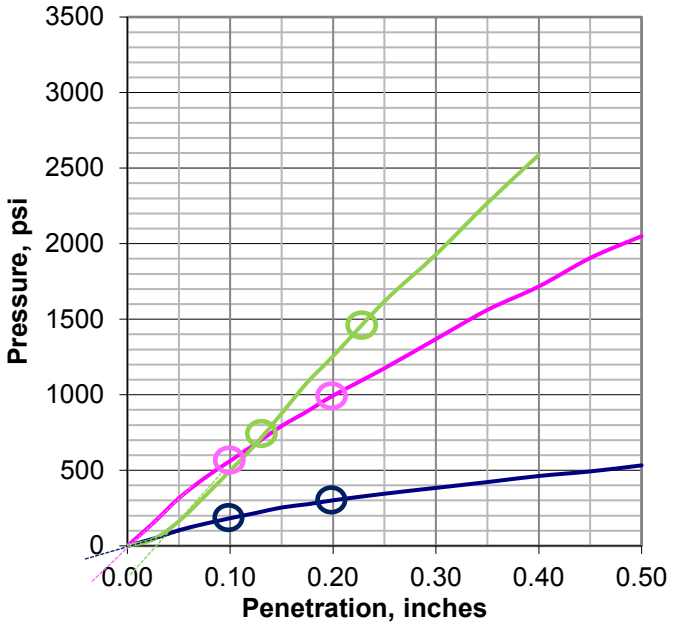
CBR Penetration Data

Penetration Piston*	Diameter	Area Face
	1.952	2.992924

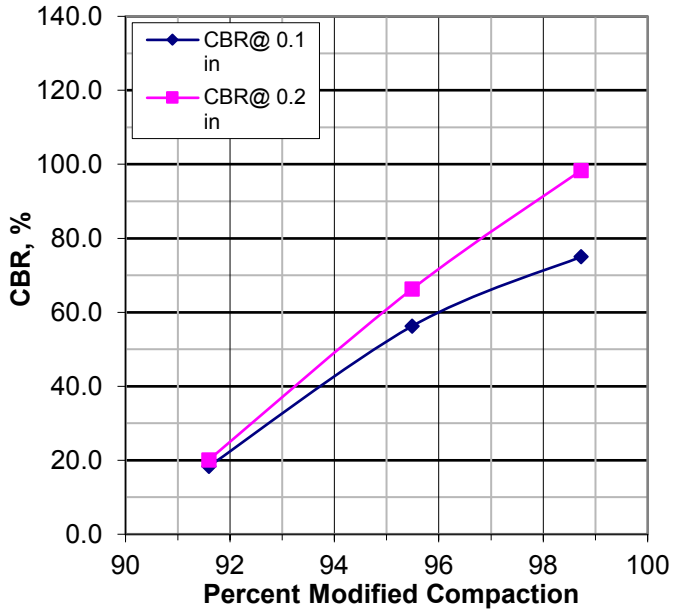
CBR Stress Strain Curve Plotting and Interpretation

Mold No.		**112**			**22**			**221**		
% Compaction		**91.6**			**95.5**			**98.7**		
Proving Ring Used*:		10,000 lb			10,000 lb			10,000 lb		
Minutes	Pen (in)	Dial	Load	Stress	Dial	Load	Stress	Dial	Load	Stress
0.0	0.000	0	0	0	0	0	0	0	0	0
0.5	0.025	140	140	47	450	450	150	127	127	42
1.0	0.050	309	309	103	942	942	315	487	487	163
1.5	0.075	435	435	145	1342	1342	448	977	977	326
2.0	0.100	548	548	183	1684	1684	563	1491	1491	498
2.5	0.125	651	651	218	2027	2027	677	2019	2019	675
3.0	0.150	760	760	254	2375	2375	794	2625	2625	877
3.5	0.175	824	824	275	2666	2666	891	3240	3240	1083
4.0	0.200	902	902	301	2976	2976	994	3757	3757	1255
5.0	0.250	1033	1033	345	3519	3519	1176	4845	4845	1619
6.0	0.300	1148	1148	384	4097	4097	1369	5771	5771	1928
7.0	0.350	1263	1263	422	4673	4673	1561	6790	6790	2269
8.0	0.400	1384	1384	462	5138	5138	1717	7744	7744	2587
9.0	0.450	1474	1474	492	5702	5702	1905	8643	8643	2888
10.0	0.500	1594	1594	533	6135	6135	2050		0	0
CBR at 0.1 in pen			18.3			56.3			75.0	
CBR at 0.2 in pen			20.1			66.3			98.3	

CBR Stress Strain Curve



CBR versus Percent Compaction



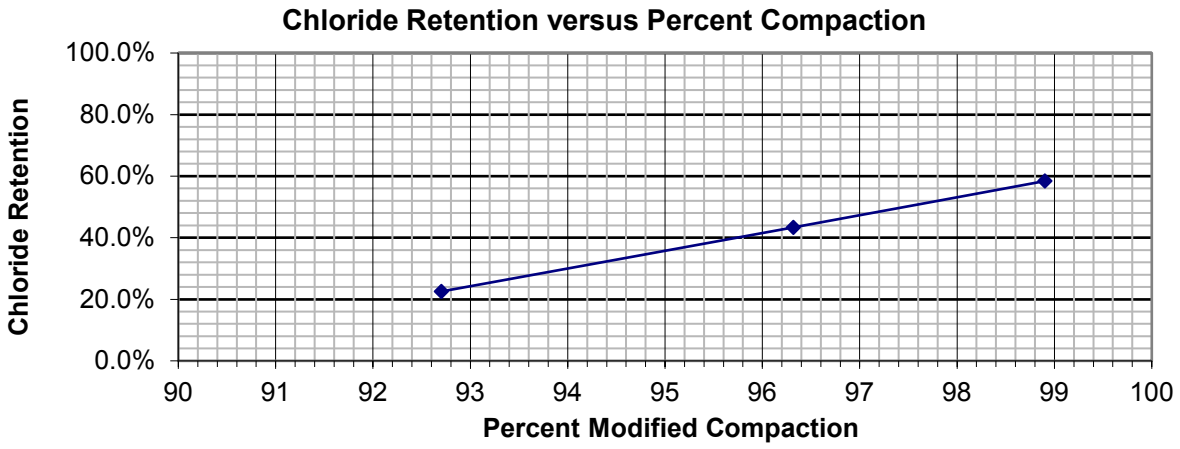
Chloride Extraction Worksheet

After CBR Penetration test, unmold each sample, break apart and dry to constant mass in 230°F (+/-9°F) oven. Then proceed with Calcium Chloride Retention testing: Place each sample in a bucket and cover with water, recording weights as indicated below.

	Mold Number & % Compaction		
	1	11	12
	92.7	96.3	98.9
Bucket ID	A	B	C
Weight Bucket, g:	516.0	514.9	515.3
Weight Bucket + Dry Sample, g:	4919.4	5116.9	5261.1
Weight Dry Sample, g:	4403.4	4602.0	4745.8
Weight Bucket + Dry Sample + Water, g:	7003.8	7350.7	7755.2
Weight Water Added, g:	2084.4	2233.8	2494.1

Stir each sample for several minutes to ensure the material is thoroughly wetted to allow $CaCl_2$ to go into solution. After stirring, cover each bucket to prevent evaporation and let sediment settle for at least 2 hours until brine is clear (settlement time may be increased or decreased as appropriate). Siphon off brine into a separate clean container (must have a minimum of 500 mL). Determine specific gravity of the solution by filling a clean, dry calibrated 500 mL pycnometer.

Weight Pycnometer, g:	181.7	181.7	181.7
Weight Pycnometer + Brine, g :	684.0	686.7	688.1
Temperature of Brine, °F:	74.9	74.2	74.0
Weight Pycnometer + Water at brine temp (from calibration chart):	680.9	680.9	680.9
Specific Gravity :	1.006	1.012	1.014
$CaCl_2$ brine concentration, % (*see graph below for equation*):	**0.71**	**1.33**	**1.65**
Weight $CaCl_2$ in Sample (total weight $CaCl_2$ in brine), g:	14.8	29.7	41.2
% $CaCl_2$ in Sample:	**0.34%**	**0.65%**	**0.88%**
% $CaCl_2$ added to sample when batched	1.5%	1.5%	1.5%
% $CaCl_2$ retained	22.5%	43.4%	58.4%



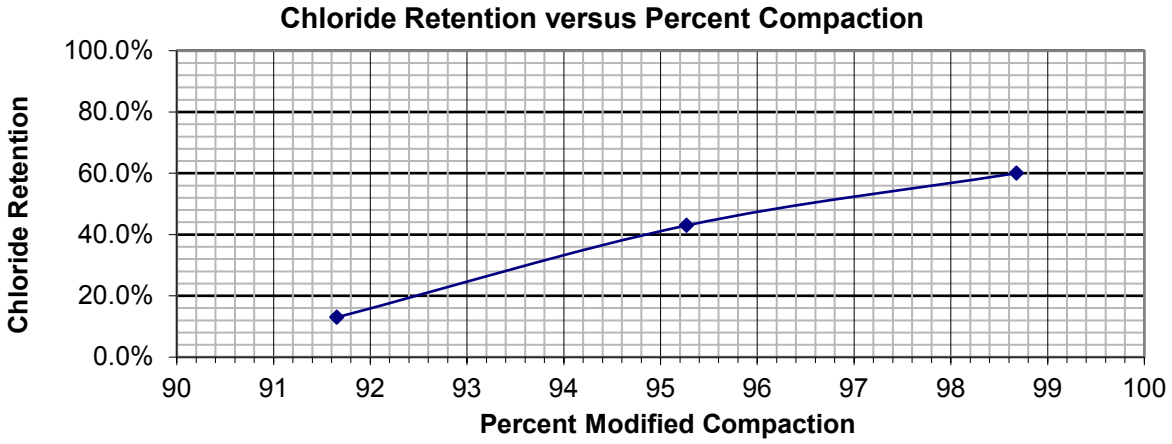
Chloride Extraction Worksheet

After CBR Penetration test, unmold each sample, break apart and dry to constant mass in 230°F (+/-9°F) oven. Then proceed with Calcium Chloride Retention testing: Place each sample in a bucket and cover with water, recording weights as indicated below.

	Mold Number & % Compaction		
	13	14	20
	91.7	95.3	98.7
Bucket ID	D	E	F
Weight Bucket, g:	516.7	516.0	515.6
Weight Bucket + Dry Sample, g:	4856.9	5062.0	5254.6
Weight Dry Sample, g:	4340.2	4546.0	4739.0
Weight Bucket + Dry Sample + Water, g:	7017.7	7212.5	7679.6
Weight Water Added, g:	2160.8	2150.5	2425.0

Stir each sample for several minutes to ensure the material is thoroughly wetted to allow $CaCl_2$ to go into solution. After stirring, cover each bucket to prevent evaporation and let sediment settle for at least 2 hours until brine is clear (settlement time may be increased or decreased as appropriate). Siphon off brine into a separate clean container (must have a minimum of 500 mL). Determine specific gravity of the solution by filling a clean, dry calibrated 500 mL pycnometer.

Weight Pycnometer, g:	181.7	181.7	181.7
Weight Pycnometer + Brine, g :	682.6	686.8	688.5
Temperature of Brine, °F:	74.4	74.0	74.2
Weight Pycnometer + Water at brine temp (from calibration chart):	680.9	680.9	680.9
Specific Gravity :	1.003	1.012	1.015
$CaCl_2$ brine concentration, % (*see graph below for equation*):	**0.39**	**1.35**	**1.74**
Weight $CaCl_2$ in Sample (total weight $CaCl_2$ in brine), g:	8.4	29.1	42.3
% $CaCl_2$ in Sample:	**0.19%**	**0.64%**	**0.90%**
% $CaCl_2$ added to sample when batched	1.5%	1.5%	1.5%
% $CaCl_2$ retained	13.0%	43.0%	60.0%



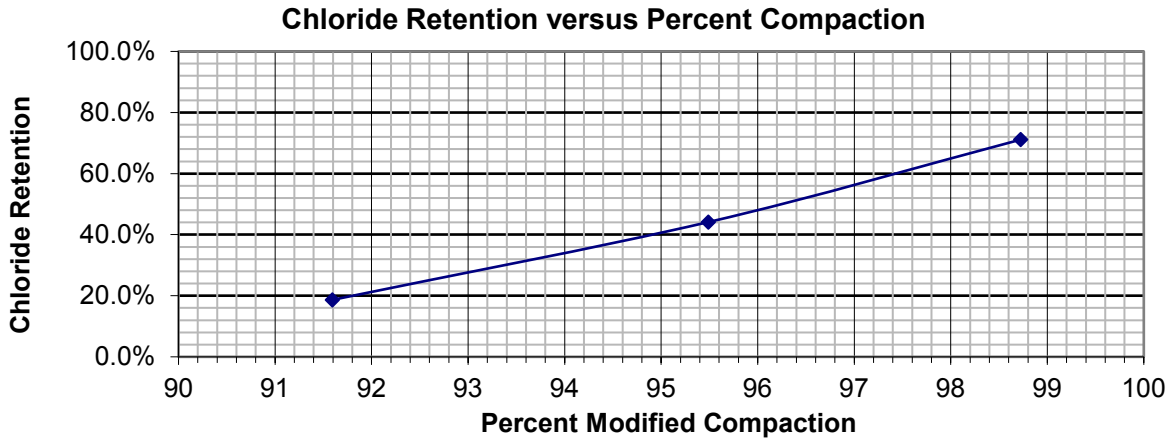
Chloride Extraction Worksheet

After CBR Penetration test, unmold each sample, break apart and dry to constant mass in 230°F (+/-9°F) oven. Then proceed with Calcium Chloride Retention testing: Place each sample in a bucket and cover with water, recording weights as indicated below.

	Mold Number & % Compaction		
	112	22	221
	91.6	95.5	98.7
Bucket ID	H	G	8
Weight Bucket, g:	515.5	515.9	511.1
Weight Bucket + Dry Sample, g:	4869.4	5065.2	5235.9
Weight Dry Sample, g:	4353.9	4549.3	4724.8
Weight Bucket + Dry Sample + Water, g:	7075.4	7134.1	7706.0
Weight Water Added, g:	2206.0	2068.9	2470.1

Stir each sample for several minutes to ensure the material is thoroughly wetted to allow $CaCl_2$ to go into solution. After stirring, cover each bucket to prevent evaporation and let sediment settle for at least 2 hours until brine is clear (settlement time may be increased or decreased as appropriate). Siphon off brine into a separate clean container (must have a minimum of 500 mL). Determine specific gravity of the solution by filling a clean, dry calibrated 500 mL pycnometer.

Weight Pycnometer, g:	181.7	181.7	181.7
Weight Pycnometer + Brine, g :	683.3	687.2	689.7
Temperature of Brine, °F:	74.2	73.5	73.7
Weight Pycnometer + Water at brine temp (from calibration chart):	680.9	680.9	680.9
Specific Gravity :	1.005	1.013	1.018
$CaCl_2$ brine concentration, % (*see graph below for equation*):	**0.55**	**1.45**	**2.02**
Weight $CaCl_2$ in Sample (total weight $CaCl_2$ in brine), g:	12.1	29.9	49.9
% $CaCl_2$ in Sample:	**0.28%**	**0.66%**	**1.07%**
% $CaCl_2$ added to sample when batched	1.5%	1.5%	1.5%
% $CaCl_2$ retained	18.7%	44.1%	71.1%

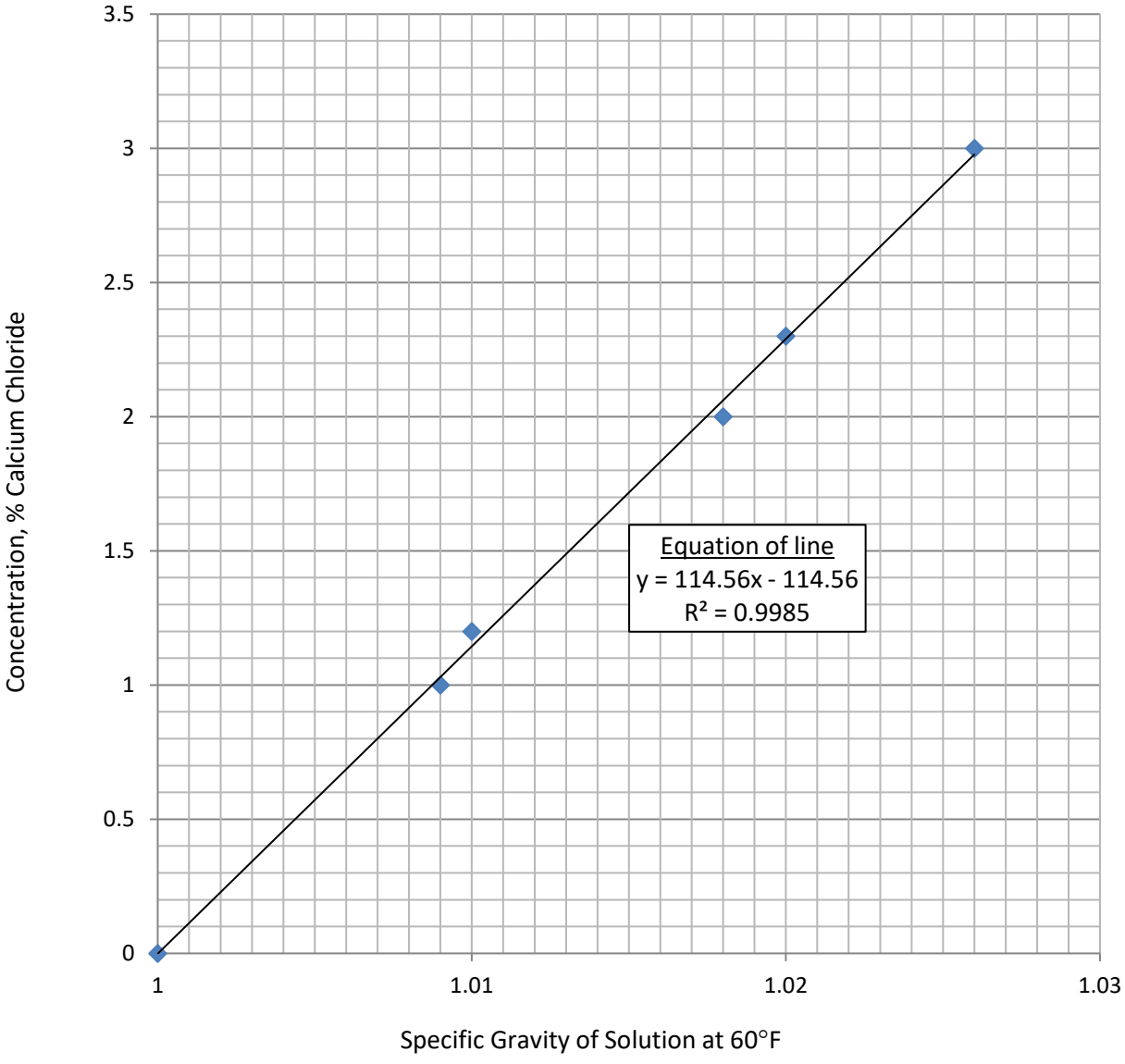


Calcium Chloride Solutions

Concentration vs. Specific Gravity (at 60°F)

for

Concentrations of 3% or less Calcium Chloride



Source:

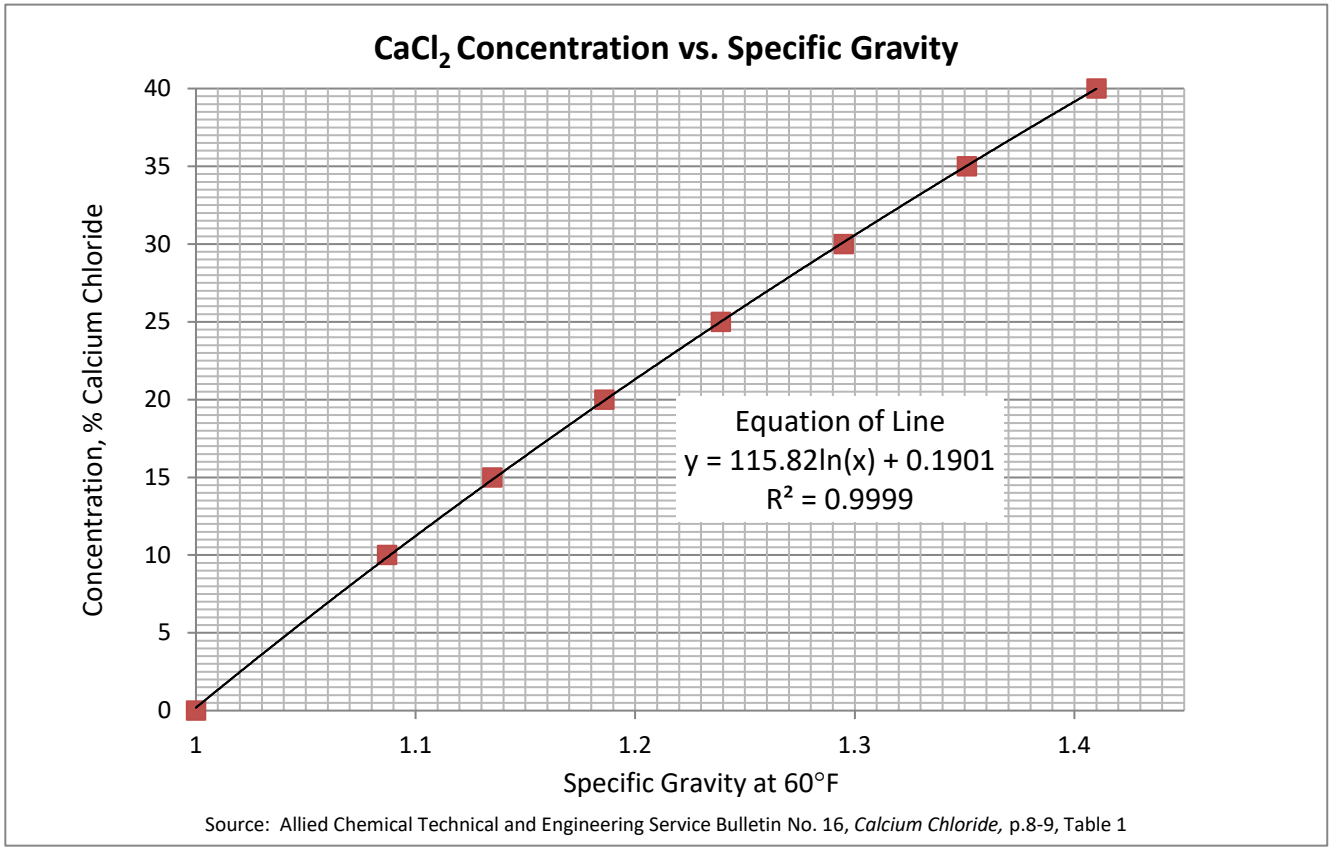
Allied Chemical Technical And Engineering Service Bulletin No. 16: *Calcium Chloride*, p.8, Table 1

Calcium Chloride Brine Preparation

It is suggested $CaCl_2$ Solution be prepared in 4 gallon batches to 38% concentration using 94% pure $CaCl_2$ pellets. Mix in a 5 gallon plastic bucket. Add solid Calcium Chloride to water and stir until completely dissolved. After stirring, allow brine to cool to room temperature. Use a 500 mL calibrated pycnometer to determine the specific gravity of the brine (ratio of weight of brine to weight of equivalent volume of water at same temperature). Skim off any brown residue that may appear on the surface of the brine with a paper towel or a fine screen prior to filling pycnometer. It is preferable to achieve a chloride concentration between 37 and 39%. Higher concentrations may precipitate calcium chloride at the low end of range of expected room temperatures. Lower concentrations may be too dilute and will result in difficulty preparing test specimens in the desired range of moisture contents. Use the summary table below to determine % concentration from the specific gravity or reference the attached chart. The following batching guidelines may be used to prepare the calcium chloride solution, but be aware that adjustments will likely be necessary based on actual measured specific gravity.

To prepare a 38% solution:

Total volume of 38% $CaCl_2$ desired, gallons:	3.1
% purity of solid CaCl2 to be used	94.0%
Weight solid CaCl2 needed, lbs:	14.5
Weight water needed, lbs:	21.4
Weight calibrated pycnometer, g:	181.7
Weight pycnometer + prepared solution, g:	880.2
Temperature solution, °F	77.2
Weight pyc + water at soln temp (from pyc calibration chart), g:	680.8
Specific gravity solution:	1.400
CaCl2 solution concentration (from chart):	**39.1**



Source: Allied Chemical Technical and Engineering Service Bulletin No. 16, *Calcium Chloride,* p.8-9, Table 1

Table 1 *(Continued)*

Densities, Concentrations and Crystallizing Temperatures of Calcium Chloride Solutions

SPECIFIC GRAVITY 60/60°F	%$CaCl_2$ ACTUAL	CRYSTALLIZATION STARTS °F	WEIGHT OF A GALLON AT 60°F LB.	POUNDS CALCIUM CHLORIDE 77-80% $CaCl_2$ (REGULAR FLAKE)*			POUNDS CALCIUM CHLORIDE 94-97% $CaCl_2$ (SUPER FLAKE)		
				PER GAL. SOLUTION	PER GAL. WATER	FINAL VOLUME GAL. AT 60°F*	PER GAL. SOLUTION	PER GAL. WATER	FINAL VOLUME GAL. AT 60°F*
1.228	**24.0**	−16.2	10.24	3.15	3.71	1.176	2.59	2.77	1.087
1.230	24.2	−17.1	10.25	3.18	3.75	1.180	2.61	2.80	1.088
1.239	**25.0**	−21.0	10.33	3.31	3.93	1.188	2.72	2.92	1.092
1.240	25.1	−21.5	10.34	3.33	3.96	1.190	2.73	2.94	1.092
1.250	**26.0**	−25.8	10.42	3.48	4.18	1.202	2.85	3.08	1.097
1.260	**27.0**	−31.2	10.50	3.64	4.42	1.215	2.98	3.25	1.104
1.270	27.8	−37.1	10.59	3.79	4.65	1.227	3.10	3.38	1.107
1.272	**28.0**	−37.8	10.60	3.81	4.68	1.228	3.12	3.41	1.108
1.280	28.7	−44.3	10.67	3.93	4.86	1.237	3.22	3.53	1.113
1.283	**29.0**	−49.4	10.70	3.98	4.94	1.241	3.26	3.57	1.116
1.290	29.6	−59.8	10.75	4.08	5.10	1.250	3.35	3.69	1.120
1.295	**30.0**	−50.8	10.80	4.16	5.23	1.256	3.42	3.77	1.122
1.300	30.5	−41.8	10.84	4.24	5.36	1.264	3.48	3.85	1.125
1.306	**31.0**	−33.2	10.89	4.33	5.51	1.271	3.55	3.94	1.128
1.310	31.3	−29.2	10.92	4.38	5.58	1.275	3.60	4.00	1.130
1.317	**32.0**	−19.5	10.98	4.50	5.79	1.287	3.69	4.12	1.135
1.320	32.2	−17.0	11.01	4.54	5.86	1.293	3.73	4.17	1.137
1.328	**33.0**	−6.9	11.07	4.68	6.11	1.305	3.85	4.32	1.143
1.330	33.2	−4.7	11.09	4.72	6.18	1.309	3.88	4.36	1.146
1.340	**34.0**	+4.3	11.17	4.87	6.45	1.324	4.00	4.52	1.152
1.350	34.9	+14.3	11.25	5.04	6.76	1.341	4.14	4.71	1.159
1.351	**35.0**	+14.4	11.26	5.05	6.78	1.343	4.15	4.73	1.160
1.360	35.8	+21.7	11.34	5.20	7.07	1.359	4.27	4.90	1.166
1.363	**36.0**	+24.1	11.36	5.24	7.14	1.363	4.30	4.98	1.168
1.370	36.4	+30.0	11.42	5.33	7.30	1.375	4.38	5.07	1.174
1.374	**37.0**	+33.4	11.46	5.44	7.54	1.386	4.43	5.14	1.177
1.380	37.4	+37.0	11.51	5.52	7.69	1.393	4.53	5.24	1.181
1.386	**38.0**	+42.1	11.56	5.63	7.93	1.407	4.61	5.37	1.187
1.390	38.3	+44.4	11.59	5.69	8.05	1.414	4.67	5.45	1.190
1.398	**39.0**	+49.6	11.66	5.83	8.35	1.431	4.79	5.62	1.198
1.400	39.2	+50.9	11.67	5.86	8.41	1.435	4.82	5.66	1.200
1.410	**40.0**	+55.9	11.76	6.03	8.79	1.457	4.95	5.85	1.207
	40.9	+61.0							
	41.0	+61.5							
	41.7	+64.8							
	42.0	+65.8							
	42.5	+68.0							
	43.0	+69.8							
	43.3	+70.9							
	44.0	+73.0							
	44.2	+73.6							
	45.0	+75.6							

Note

At concentrations above 40.8% calcium chloride solutions contain suspended crystals at 60°F., and therefore hydrometer readings at 60°F. are of little value. For data at higher concentrations and temperatures see tables on pages 11, 12, 13 and 14.

*Final volume in gallons at 60°F. when quantity of flake calcium chloride shown in pre-